supplies would be 50 tons per year during the construction phase and 67 tons per year during the operations and monitoring phase; emissions would contribute a maximum of an additional 0.07 percent to the estimated 2000 daily carbon-monoxide levels in the nonattainment area (DIRS 156706-Clark County 2000, Appendix A, Table 1-3).

Impacts in other environmental resource areas would be unlikely to occur.

6.2 National Transportation

This section describes the estimated national transportation impacts from shipping spent nuclear fuel and high-level radioactive waste from 72 commercial and 5 DOE sites throughout the United States to the proposed Yucca Mountain Repository. This section includes the following:

- Definition and an overview of the analysis scenarios (Section 6.2.1)
- Impacts to workers and the public from spent nuclear fuel and high-level radioactive waste loading operations at commercial and DOE sites (Section 6.2.2)
- Potential incident-free (routine) radiological impacts and vehicle emission impacts (Section 6.2.3)
- Potential accident scenario impacts (Section 6.2.4).

National transportation of spent nuclear fuel and high-level radioactive waste, which would use existing highways and railroads, would average 7.8 million truck kilometers (4.9 million miles) per year for the mostly truck case and 1.6 million railcar kilometers (1 million miles) per year for the mostly rail case. Barges used to ship rail casks to nearby railheads from commercial sites not served by a railroad could average as much as 6,500 kilometers (4,000 miles) per year. The national yearly average for total highway and railroad traffic is 186 billion truck kilometers (116 billion miles) and 49 billion railcar kilometers (30 billion miles) (DIRS 150989-BTS 1998, pp. 5 and 6)]. Spent nuclear fuel and high-level radioactive waste transportation would represent a very small fraction of the total national highway and railroad traffic (0.004 percent of truck kilometers and 0.003 percent of railcar kilometers). Domestic waterborne trade in 1995 accounted for about 1 billion metric tons (910 million tons) (DIRS 148158-MARAD 1998, all). This represents about 1 million barge shipments per year. Thus, shipments of spent nuclear fuel by barge would only be a very small fraction of the total annual domestic waterborne commerce.

With the exception of occupational and public health and safety impacts, which are evaluated in this section, the environmental impacts of this small fraction of all national transportation would be very small in comparison to the impacts of other nationwide transportation activities. Thus, the national transportation of spent nuclear fuel and high-level radioactive waste would have very small impacts on land use and ownership; hydrology; biological resources and soils; cultural resources; socioeconomics; noise and vibration; aesthetics; utilities, energy, and materials; or waste management.

To determine if pollutants of concern from national transportation vehicles (truck and rail) would degrade air quality in nonattainment areas, DOE reviewed traffic volumes in these areas. This review determined that the numbers of shipments of Yucca Mountain-destined vehicles through these areas would be very small in relation to normal traffic volumes. Therefore, the impact to air quality in these areas, except Nevada (see Section 6.1.3), would be very small.

Radiological impacts of accidents on biological resources would be extremely unlikely. The analysis focused the impacts from accidents on human health and safety. A severe accident scenario, such as the maximum reasonably foreseeable accident scenarios discussed in Section 6.2.4.2, that would cause a release of contaminated materials would be very unlikely. The probabilities of the severe accident scenarios discussed in Section 6.2.4.2 are less than 3 in 10 million per year for both the mostly legal-weight truck and mostly rail transportation scenarios. Because of the low probability of occurrence, an accident scenario during the transport of spent nuclear fuel and high-level radioactive waste would be unlikely to cause adverse impacts to any endangered or threatened species, and impacts to other plants and animals would be small. Therefore, the analysis did not evaluate the impacts for these environmental parameters for national transportation activities further.

This chapter does not evaluate the risks of economic loss or resultant environmental consequences from potential transportation accidents that could cause releases of radioactive materials. DOE did not perform these analyses because estimating economic risks and environmental consequences would depend on many factors associated with accidents that cannot be known in advance. Therefore, the information that would be needed for such an analysis is not available. Section J.1.4.2.5 of Appendix J presents a review and analysis of studies by the U.S. Nuclear Regulatory Commission, the National Aeronautics and Space Administration, DOE, and others that discusses cost factors and provides estimates of the range of costs and environmental consequences of cleaning up contamination following hypothetical accidental releases of radioactive materials.

6.2.1 ANALYSIS SCENARIOS AND METHODS

Under the mostly legal-weight truck scenario for national transportation, DOE would transport shipments (with the exception of naval spent nuclear fuel and possibly some DOE high-level radioactive waste) by legal-weight truck to Nevada. Naval spent nuclear fuel would be shipped by rail from the Idaho National Engineering and Environmental Laboratory. Under the mostly-legal weight truck scenario, DOE assumed that some shipments of DOE high-level radioactive waste would use *overweight trucks*. With the exception of permit requirements and operating restrictions, the vehicles for these shipments would be similar to legal-weight truck shipments but might weigh as much as 52,200 kilograms (115,000 pounds). States routinely issue special permits for trucks weighing up to 58,500 kilograms (129,000 pounds).

Figure 6-11 shows the highway routes (mostly Interstate Highways) that the analysis used to estimate transportation-related impacts, along with the locations of the commercial and DOE sites and Yucca Mountain. The routes selected for analysis are representative of routes that DOE could use for truck shipments if the Yucca Mountain site was approved. In addition, the highway routes shown would conform to the routing requirements in 40 CFR 397.101 (see Appendix J, Section J.1.2).

Although DOE cannot be certain of the actual mix of rail and truck shipments that would occur, it expects that the mostly rail scenario best represents the mix of modes it would use. This belief is based on analyses the Department has done to assess generator site capabilities to handle larger (rail) casks, distances to suitable railheads, and historic experience in actual shipments of fuel, waste, or large reactor-related components. In addition, DOE considered relevant information published by knowledgeable sources such as the Nuclear Energy Institute, which provided information on capabilities of generator sites to handle large rail casks (DIRS 155777-McCullum 2000, all). Although DOE believes the mostly rail scenario best represents what would be likely for the transportation of spent nuclear fuel and high-level radioactive waste to a Yucca Mountain Repository, Appendix J, Section J.1.2.1.4 describes an analysis that illustrates how changes in the mix of rail and truck modes would change estimated health and safety impacts for national transportation. The results of the analysis indicated how a mix between the limits represented by the mostly legal-weight truck and mostly rail scenarios would result in health and safety impacts that would be between those estimated for the two scenarios and would not be greater than the impacts from either scenario.

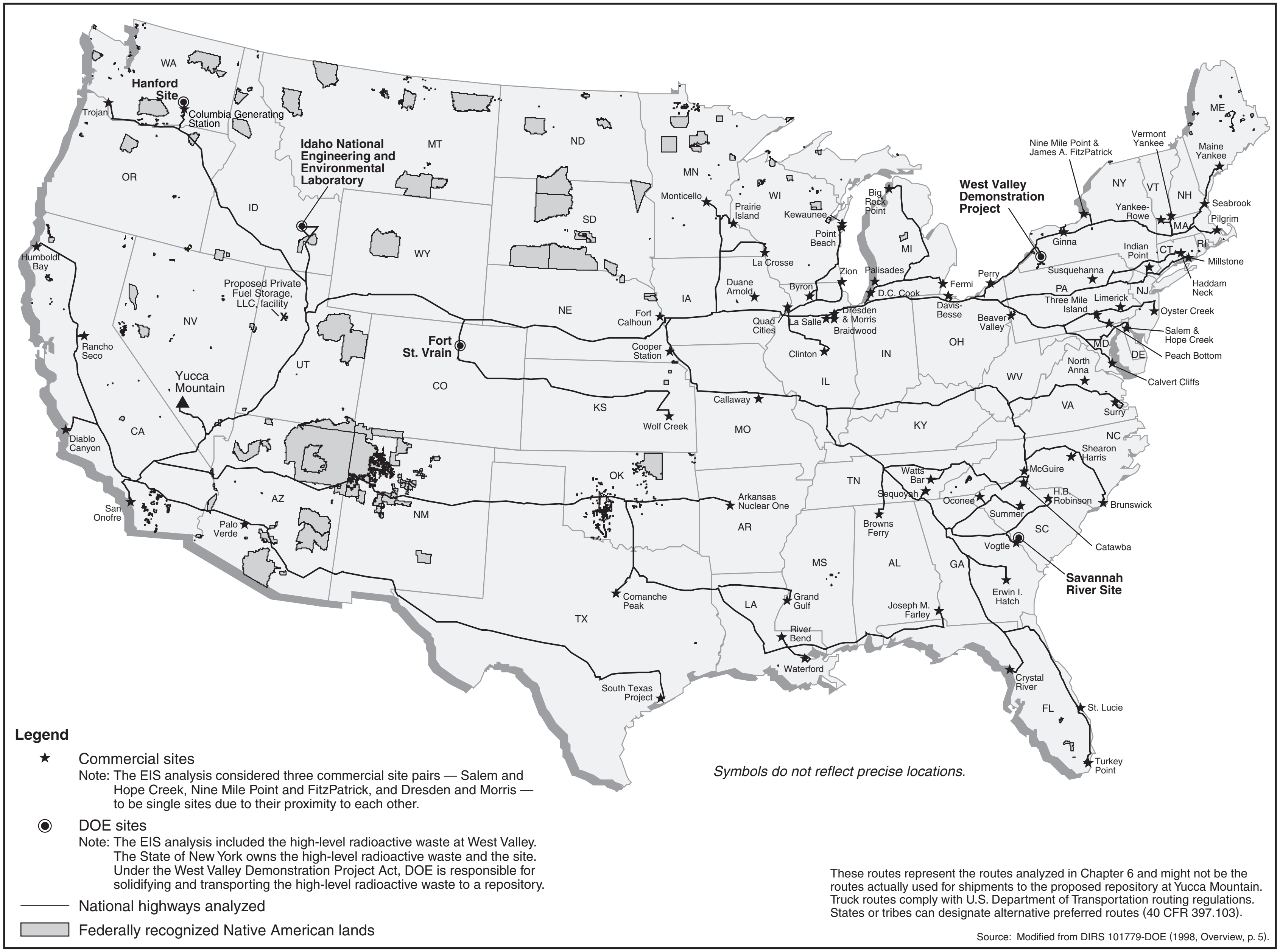

Figure 6-11. Representative truck routes from commercial and DOE sites to Yucca Mountain analyzed for the Proposed Action.

MOSTLY LEGAL-WEIGHT TRUCK AND MOSTLY RAIL SCENARIOS

The Department would prefer most shipments to a Yucca Mountain repository be made using rail transportation. It also expects that the mostly rail scenario described in this EIS best represents the mix of rail and truck transportation that would be used. However, it cannot be certain of the actual mix of rail and truck transportation that would occur over the 24 years of the Proposed Action. Consequently, DOE used the mostly legal-weight truck and mostly rail scenarios as a basis for the analysis of potential impacts to ensure the analysis addressed the range of possible transportation impacts. The estimated number of shipments for the mostly legal-weight truck and mostly rail scenarios represents the two extremes in the possible mix of transportation modes, thereby covering the range of potential impacts to human health and safety and to the environment for the transportation modes DOE could use for the Proposed Action.

Under the national transportation mostly rail scenario, DOE would transport shipments (with the exception of commercial spent nuclear fuel at six sites that do not have the capability to load a rail cask) by rail to Nevada. In addition, this scenario assumes that 24 commercial sites that have the capability to handle and load rail casks, but that do not have railroad service, would make shipments to nearby railheads by barge or heavy-haul truck. Barge shipments of rail casks containing spent nuclear fuel could be possible from 17 commercial sites that are on or near navigable waterways. Figure 6-12 shows the railroad routes that the analysis used to estimate transportation-related impacts, along with the locations of the commercial and DOE sites and Yucca Mountain. The routes selected for analysis are representative of routes that could be used for rail shipments if the Yucca Mountain site was approved. The analysis estimated that these routes would most closely follow current railroad industry practices and the system-wide capability to ship hazardous materials safely. These routes would reduce time in transit, reduce the number of interchanges between railroads, and use mainline tracks to the maximum practical extent.

The railroad routes shown in Figure 6-12 could also be used by generators to transport spent nuclear fuel to a proposed Private Fuel Storage facility near Skull Valley in northwestern Utah (DIRS 152001-NRC 2000, all). Rail routes from that facility to connections with potential branch rail lines or to an intermodal transfer station in Nevada would be essentially the same as the western sections of rail routes analyzed in this chapter. Thus, impacts presented in this chapter for five candidate routes for heavy-haul trucks and five candidate rail corridors in Nevada would be about the same whether shipments were directly from 72 commercial and 5 DOE generator sites to a Yucca Mountain Repository or from a Private Fuel Storage facility in Skull Valley, Utah. Chapter 8, Section 8.4, discusses potential cumulative impacts of transporting commercial spent nuclear fuel to a Private Fuel Storage facility and then to a Yucca Mountain Repository (see Appendix J, Section J.1.2).

This section evaluates radiological and nonradiological impacts to workers and the public from routine transportation operations and from accidents. DOE used a number of computer models and programs to estimate these impacts; Appendix J describes the analysis assumptions and models.

The CALVIN model (DIRS 155644-CRWMS M&O 1999, pp. 2 to 22) was used to estimate the number of shipments of commercial spent nuclear fuel for both the mostly legal-weight truck and mostly rail scenarios. The CALVIN program used commercial spent nuclear fuel inventories and characteristics from the *Report on the Status of the Final 1995 RW-859 Data Set* (DIRS 104848-CRWMS M&O 1996, all) and the *Calculation Method for the Projection of Future SNF Discharges* (DIRS 156305-CRWMS M&O 2001, all) (see Appendix A) to estimate the number of shipments. For DOE spent nuclear fuel and high-level radioactive waste, the analysis used inventories and characteristics for materials to be shipped under the Proposed Action that were reported by the DOE sites in 1998 (see Appendix A) to estimate the number of shipments. Chapter 2, Section 2.1.3, and Appendix J discuss the number of shipments.

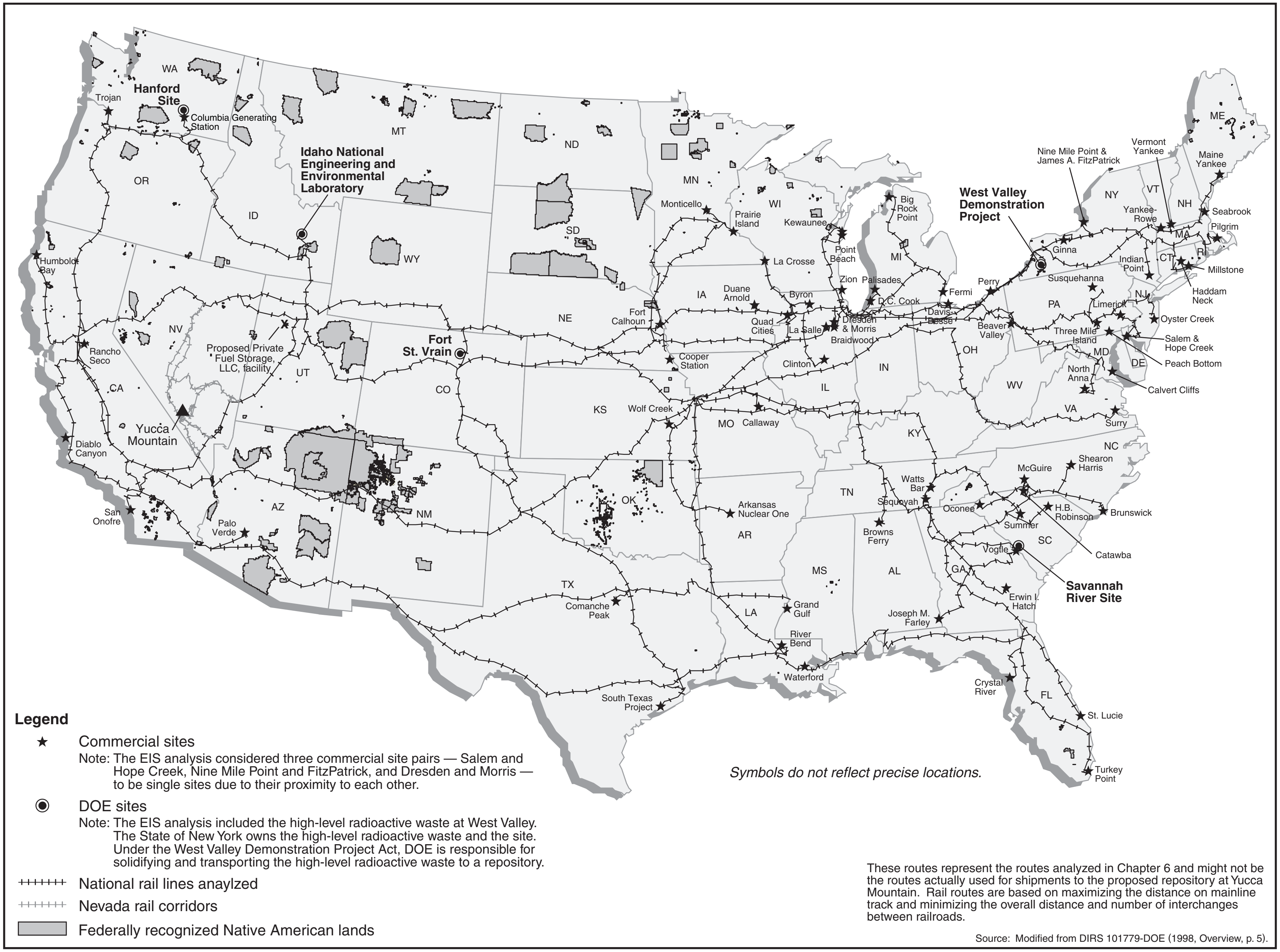

Figure 6-12. Representative rail routes from commercial and DOE sites to Yucca Mountain analyzed for the Proposed Action.

The transportation analyses used the following computer programs:

- HIGHWAY (DIRS 104780-Johnson et al. 1993, all) to identify the highway routes that it could use to transport spent nuclear fuel and high-level radioactive waste. All of the routes would satisfy U.S. Department of Transportation route selection regulations.
- INTERLINE (DIRS 104781-Johnson et al. 1993, all) to identify rail and barge routes for the analysis.
- RADTRAN 5 (DIRS 150898-Neuhauser and Kanipe 2000, all; DIRS 155430 Neuhauser, Kanipe, and Weiner 2000, all) to estimate radiological dose risk to populations and transportation workers during routine operations. The analyses also used this program to estimate radiological dose risks to populations and transportation workers from accidents.
- RISKIND (DIRS 101483-Yuan et al. 1995, all) to estimate radiological doses to the maximally exposed individuals and to the population during routine transportation. This program also estimated radiological doses to the maximally exposed individuals and to the population from transportation accidents.

6.2.2 IMPACTS FROM LOADING OPERATIONS

This section describes potential impacts from loading spent nuclear fuel and high-level radioactive waste in transportation casks and on transportation vehicles at the 72 commercial and 5 DOE sites. It also describes methods for estimating radiological and industrial hazard impacts from routine loading operations and radiological impacts of loading accidents to workers and members of the public. During loading operations, radiological impacts to workers could occur from normal operations and accidents. In addition, workers could experience impacts from industrial hazards. Members of the public could experience radiological impacts if a loading accident occurred but would not experience impacts from industrial hazards, including hazards associated with nonradioactive hazardous materials. Nonradioactive hazardous materials would be used only in small quantities, if at all, in loading operations. Chapter 4 addresses impacts from unloading operations at the repository.

6.2.2.1 Radiological Impacts of Routine Operations

Radiological impacts to members of the public from routine operations would be very small. An earlier DOE analysis estimated that public dose from loading operations (primarily due to atmospheric effluents) would be less than 0.001 person-rem per metric ton of uranium loaded (DIRS 104731-DOE 1986, Volume 2, p. E.6) (see Appendix J for more information). Therefore, to be conservative this analysis estimated the dose to the public from loading operations by multiplying the value of 0.001 person-rem per metric ton of uranium by the 70,000 metric tons (77,000 tons) of spent nuclear fuel and high-level radioactive waste DOE would transport under the Proposed Action. [DIRS 104731-DOE (1986, Volume 2, all) uses the term “metric ton uranium,” which is essentially the same as metric tons of heavy metal for commercial spent nuclear fuel.] The resulting population dose would be 70 person-rem, which, based on conversion factors recommended by the International Commission on Radiological Protection, would result in 0.04 latent cancer fatality. The Commission recommends 0.0004 and 0.0005 latent cancer fatality per person-rem for involved worker populations and the general public, respectively (DIRS 101836-ICRP 1991, p. 22).

Table 6-6 lists estimated involved worker impacts from loading spent nuclear fuel at commercial sites and loading DOE spent nuclear fuel and high-level radioactive waste at DOE facilities for shipment to the Yucca Mountain site under the Proposed Action. The impacts assume worker rotation and other administrative actions at commercial sites would follow guidance similar to that in *DOE Standard - Radiological Control Manual* (DIRS 156764-DOE 1999, Article 211). Although the guidance that the annual dose received by an individual worker could be as high as 2 rem per year, DOE policy is to limit doses to individual workers to no more than 500 millirem per year. The maximum individual dose would be 12 rem over the 24 years of loading operations for individuals who worked the entire duration of repository operations. The estimated probability of a latent cancer fatality for an involved worker from this dose would be about 0.005 (5 chances in 1,000).

Table 6-6. Estimated radiological impacts to involved workers from loading operations.[a]

Impact	Mostly rail	Mostly legal-weight truck
Maximally exposed individual		
Dose (rem)	12[b]	12[b]
Probability of LCF[c]	0.005	0.005
Involved worker population[d]		
Dose (person-rem)	4,200	15,000
Number of LCFs	1.7	6.1

a. Numbers are rounded.
b. Based on 500-millirem-per-year administrative dose limit.
c. LCF = latent cancer fatality.
d. All involved workers at all facilities, preparing about 11,000 shipments under the mostly rail scenario and about 53,000 shipments under the mostly legal-weight truck scenario over 24 years.

As many as 2 latent cancer fatalities from the mostly rail scenario and about 6 latent cancer fatalities from the legal-weight truck scenario could result in the involved worker population over 24 years. The mostly legal-weight truck scenario would result in more potential impacts than the mostly rail scenario because of the increased exposure time needed to load more transportation casks.

To assess potential radiological impacts at generator facilities, the EIS analysis assumed that noninvolved workers would have no direct involvement with handling spent nuclear fuel or high-level radioactive waste. DOE expects radiological impacts to noninvolved workers to be even smaller than those to involved workers.

6.2.2.2 Impacts from Industrial Hazards

Table 6-7 lists estimated impacts to involved workers from industrial hazards over 24 years of loading operations at the 77 sites. Fatalities from industrial hazards would be unlikely from loading activities under either national transportation scenario. The mostly legal-weight truck scenario would have about three times the estimated number of total recordable cases and lost workday cases of the mostly rail scenario because there would be more shipments and more work time (full-time equivalent worker years). Using the assumption that the noninvolved workforce would be 25 percent of the number of involved workers, the analysis determined that impacts to noninvolved workers would be about 25 percent of those listed in Table 6-7.

Table 6-7. Impacts to involved workers[a] from industrial hazards during loading operations.[b]

Impact	Mostly rail	Mostly legal-weight truck
Total recordable cases[c]	130	380
Lost workday cases[d]	67	200
Fatalities[e]	0.29	0.9

a. Includes all involved workers at all facilities during 24 years of repository operations. During the 24 years of shipments to the proposed repository, these workers would put in 1,300 worker years (2,080 hours per worker year) preparing about 11,000 shipments under the mostly rail scenario and 3,700 worker years preparing about 53,000 legal-weight truck shipments and 300 naval spent nuclear fuel rail shipments under the mostly legal-weight truck scenario. Industrial safety impacts in the noninvolved workforce would be about 25 percent of those listed.
b. Numbers are rounded to two significant digits.
c. Total recordable cases (injury and illness) based on a 1998 loss incident rate of 0.08.
d. Lost workday cases based on a 1998 loss incident rate of 0.05.
e. Fatalities based on a 1998 loss incident rate of 0.000218.

To assess potential industrial safety impacts at generator facilities, the EIS analysis assumed that noninvolved workers would be persons with office-based administrative duties associated with loading operations. In addition to industrial safety impacts, traffic fatality and vehicle emissions impacts as a result of commuting workers associated with loading operations were estimated. Traffic involving commuting workers could result in 0.4 fatality under the mostly legal-weight truck scenario and 0.2 fatality under the mostly rail scenario. Estimated vehicle emissions impacts from commuting could result in 0.06 latent fatalities for the mostly legal-weight truck scenario and 0.02 for the mostly rail scenario.

6.2.3 NATIONAL TRANSPORTATION IMPACTS

The following sections discuss the impacts of transporting spent nuclear fuel and high-level radioactive waste to the proposed Yucca Mountain Repository under the mostly legal-weight truck and mostly rail scenarios. The analysis in this section addresses the impacts of incident-free transportation. Section 6.2.4 discusses accidents, and Appendix J contains the details of the analysis and its assumptions.

6.2.3.1 Impacts from Incident-Free Transportation – National Mostly Legal-Weight Truck Transportation Scenario

This section addresses radiological and nonradiological impacts to populations and maximally exposed individuals for incident-free transportation of spent nuclear fuel and high-level radioactive waste for the mostly-legal weight truck scenario.

Incident-Free Radiological Impacts to Populations. Table 6-8 lists the incident-free population dose and latent cancer fatalities to workers and the public for the mostly legal-weight truck scenario. The impacts include those for the shipment of naval spent nuclear fuel by rail to Nevada, intermodal transfer of rail casks to heavy-haul trucks, and subsequent heavy-haul transportation to the proposed repository. Section 6.3.3 and Appendix J contain additional information on worker impacts from intermodal transfer operations. Worker impacts would include radiological exposures of security escorts for legal-weight truck, rail, and heavy-haul truck shipments and from the transfer of naval spent nuclear fuel shipments from rail to heavy-haul truck. The collective dose to the security escorts traveling in separate vehicles would be about 6 person-rem for legal-weight truck shipments. Doses to escorts of rail shipments of naval spent nuclear fuel, who would travel in railcars in sight of but separated from the cask cars, followed by escorted heavy-haul truck shipments in Nevada would be about 0.4 person-rem.

Table 6-8. Population doses and impacts from incident-free transportation for national mostly legal-weight truck scenario.[a]

Category	Legal-weight truck shipments	Rail shipments of naval spent nuclear fuel[b]	Totals[d]
Involved workers			
Collective dose (person-rem)	14,000	29	14,000
Estimated LCFs[c]	5.6	0.01	5.6
Public			
Collective dose (person-rem)	5,000	20	5,000
Estimated LCFs	2.5	0.01	2.5

a. Impacts are totals for shipments over 24 years.
b. Includes impacts from intermodal transfer operations (see Section 6.3.3.1).
c. LCF = latent cancer fatality.
d. Totals might differ from sums of values due to rounding.

If escorts accompanied legal-weight truck shipments over the full length of their shipment routes, rather than only in highly populated urban areas as required by Federal regulations (10 CFR 73.37), the estimated doses to escorts over 24 years would be 360 person-rem (a 0.14 probability of a latent cancer fatality in the population of escorts).

In addition, as is recommended by the Commercial Vehicle Safety Alliance (DIRS 155863-CVSA 2000, all), the analysis assumed state safety inspections of shipments would occur only in originating and destination states. If inspections were conducted for every shipment in each state through which the shipment would pass, inspectors would receive an additional dose of 7,000 person-rem (about 2.8 latent cancer fatalities) over 24 years.

Appendix J, Section J.1.3.2.2.2 contains additional information about the analysis of impacts to escorts and inspectors.

The estimated radiological impacts would be 6 (5.6) latent cancer fatalities for workers and 3 (2.5) latent cancer fatalities for members of the public for the 24 years of operation. The population within 800 meters (0.5 mile) of routes would be about 10 million based on projections to 2035. About 2.3 million members of this population would be likely to incur fatal cancers from all other causes not associated with the Proposed Action (DIRS 153066-Murphy 2000, p. 5).

Incident-Free Radiological Impacts to Maximally Exposed Individuals. Table 6-9 lists estimates of doses and radiological impacts for maximally exposed individuals for the legal-weight truck scenario (which considers drivers and security escorts). The risks are calculated for the 24 years of shipment activities. Appendix J discusses analysis methods and assumptions. State inspectors who conducted frequent inspections of shipments of spent nuclear fuel and high-level radioactive waste and transportation vehicle operating crews would receive the highest annual radiation doses.

Table 6-9. Estimated doses and radiological impacts to maximally exposed individuals for national mostly legal-weight truck scenario.[a,b]

Individual	Dose (rem)	Probability of latent fatal cancer
Involved workers		
Crew member (including driver)	48[c]	0.02
Inspector	48[c]	0.02
Railyard crew member	0.13	0.00005
Public		
Resident along route	0.006	0.000003
Person in traffic jam	0.016[d]	0.000008
Person at service station	2.4[e]	0.0012
Resident near rail stop	0.009	0.000005

a. The assumed external dose rate is 10 millirem per hour at 2 meters (6.6 feet) from the vehicle for all shipments.
b. Totals for 24 years of operations.
c. Based on 2-rem-per-year administrative dose limit. If a lower dose limit, for example 500 millirem per year, was imposed for transportation workers or state inspectors, maximally exposed individual doses would be lower. See DIRS 156764-DOE (1999, Article 211) for DOE guidance on occupational dose limits.
d. Person in a traffic jam is assumed to be exposed one time only.
e. Assumes the person works at the service station for all 24 years of operations. Mitigation would be required to reduce impacts to members of the public to below 100 millirem per year.

Impacts to the maximally exposed individuals in the general public would be very low. The highest impacts would be to a service station employee who worked at a station where the analysis assumed all truck shipments would stop under the mostly legal-weight truck scenario (Table 6-9). The analysis estimated that this employee would receive a dose of 2.4 rem over 24 years, which corresponds to the maximum that would be allowed (100 millirem per year) for a member of the general public under regulations in 10 CFR Part 20. The estimate assumes that measures would be taken by DOE to reduce the dose to the employee from 130 millirem per year (3.2 rem over 24 years)—the dose estimated by the analysis if dose reduction measures were not implemented. The estimate of 3.2 rem over 24 years conservatively assumed the person would be exposed to 450 truck shipments each year for 24 years. For perspective, under the mostly legal-weight truck scenario, which assumes an average of 2,200 legal-weight truck shipments per year, about 450 truck shipments would pass through the Mercury, Nevada, gate to the Nevada Test Site in 1,800 hours. A worker at a truck stop along the route to Mercury would work about 1,800 hours per year. Thus, if every shipment stopped at that truck stop, the maximum number of shipments the worker would be exposed to in a year would be 450.

Impacts from Vehicle Emissions. Using data published by DIRS 151198-Biwer and Butler (1999, p. 1165 to 1166), DIRS 155786-EPA (1997, all), and DIRS 155780-EPA (1993, Section 13.2.13) (see Appendix J, Section J.1.3.2.3), DOE estimated the number of fatalities that vehicle emissions from shipments to Yucca Mountain could cause (Table 6-10). These potential impacts would result principally from exposure to increases in levels of pollutants, where the additional pollutants would come from vehicles transporting spent nuclear fuel and high-level radioactive waste and the accompanying escort vehicles. In the context of the number of vehicle kilometers from shipments to the Yucca Mountain site, these emissions would be very small in comparison to the emissions from other vehicles.

Table 6-10. Population health impacts from vehicle emissions during incident-free transportation for national mostly legal-weight truck scenario.[a]

Category	Legal-weight truck shipments	Rail shipments of naval spent nuclear fuel	Total[b]
Estimated vehicle emission-related fatalities	0.93	0.01	0.95

a. Impacts are totals for shipments over 24 years.
b. Total differs from sums of values due to rounding.

This section addresses radiological and nonradiological impacts to populations and maximally exposed individuals from the incident-free transportation of spent nuclear fuel and high-level radioactive waste for the mostly rail national transportation scenario. In addition, it identifies impacts of legal-weight truck shipments that would occur under the mostly rail scenario for the six commercial sites that do not have the capability to load rail casks (about 1,079 legal-weight truck shipments over 24 years). Of these six sites, two have direct rail access and four have indirect access. Of the four sites with indirect access, three have barge access. The analysis assumed that the six legal-weight truck sites would upgrade their crane capacities and ship by rail after reactor shutdown.

6.2.3.2 Impacts from Incident-Free Transportation – National Mostly Rail Transportation Scenario

For this analysis, DOE assumed that it would use either a branch rail line or heavy-haul trucks in Nevada to transport rail casks to and from the repository. Accordingly, the results indicate the range of impacts for the rail and heavy-haul truck implementing alternatives that DOE could use for transportation to the repository after rail shipments arrived in Nevada. Section 6.3 and Appendix J present more information on the analysis of the environmental impacts of the Nevada rail and heavy-haul implementing alternatives. Appendix J, Section J.2, also presents a comparison of the effects of using dedicated trains or general freight services for rail shipments.

The mostly rail scenario assumes that the 24 commercial sites not served by a railroad but with the capability to handle rail casks would use heavy-haul trucks to transport the casks to railheads for transfer to railcars. In addition, 17 of the 24 sites are adjacent to navigable waterways. At some of the 17 sites on navigable waterways, barges could be used for the initial trip segments (see Appendix J, Section J.2.1). The impacts estimated by the analysis include the impacts of heavy-haul truck or barge shipments of rail casks from the 24 sites to nearby railheads.

The analysis assumed that the truck shipments of spent nuclear fuel and high-level radioactive waste would make periodic stops for state inspections, changes of drivers, rest, and fuel. Rail shipments would

VEHICLE EMISSION UNIT RISK FACTORS

DIRS 151198-Biwer and Butler (1999, all) presents unit risk factors for estimating vehicle emissions and the resulting health effects (fatalities) from truck and rail transportation. Changes to information used in the Biwer and Butler analysis resulted in revised factors used in the analyses in this EIS. DOE made four changes:

- *Fugitive dust emission factor*. Biwer and Butler used the paved road fugitive dust emission factor equation from DIRS 155786-EPA (1997, Volume 1, Supplement D, Section 13.2.1) to estimate fugitive dust emission factors for individual vehicle weight classes. The emission factor used in the Final EIS analysis is based on the fleet average weight, as recommended in the reference.

- *Diesel exhaust emission factor*. Biwer and Butler used diesel exhaust emission factors for trucks operating in 1995. The Final EIS analysis used information presented in the *Motor Vehicle-Related Air Toxics Study* (DIRS 155780-EPA 1993, all) to estimate diesel exhaust emission factors projected for the fleet of trucks operating in 2010.

- *Mortality rate used to estimate health effects*. The PM_{10} risk factor used in Biwer and Butler was calculated using a baseline mortality rate of 0.008. This is the crude rate, which is influenced by age differences in population composition. The analysis for the Final EIS used an age-adjusted mortality rate of 0.005.

- *PM_{10} risk factor*. The PM_{10} health risk factor used by Biwer and Butler was based on an upper bound reported by DIRS 152600-Ostro and Chestnut (1998, all), who also presented lower-bound and central estimates. To avoid compounding conservative assumptions, the Final EIS analysis uses the central estimate.

These changes resulted in values for vehicle emission health effect (fatality) unit risk factors that are about a factor of 30 smaller that those estimated by DIRS 151198-Biwer and Butler (1999, all).

also make periodic stops. However, the assumed frequency of the stops and the numbers of people nearby would be different from those for truck shipments and would result in a lower dose.

Incident-Free Radiological Impacts to Populations. Table 6-11 lists incident-free radiological impacts that would occur during the routine transportation of spent nuclear fuel and high-level radioactive waste under the mostly rail national transportation scenario. Because national impacts would result from transportation from the commercial and DOE sites to the repository, they include impacts from a Nevada rail or heavy-haul truck implementing alternative. For the case in which rail shipments would continue in Nevada, total impacts to members of the general public would differ depending on the implementing alternative (see Section 6.3.2 for additional details). The range of values listed in Table 6-11 includes the range of impacts from the Nevada implementing alternatives.

About 1 latent cancer fatality could result from shipments of spent nuclear fuel and high-level radioactive waste under the mostly rail scenario over 24 years. The latent cancer fatality would occur over the lifetime of an individual in the exposed population. The population within 800 meters (0.5 mile) of routes in which this fatality would occur would be approximately 16.4 million. Approximately 3.8 million members of this population would incur fatal cancers from all other causes not associated with the Proposed Action (DIRS 153066-Murphy 2000, p. 5).

Incident-Free Radiological Impacts to Maximally Exposed Individuals. Table 6-12 lists the results of risk calculations for maximally exposed individuals for the mostly rail transportation scenario over 24 years. Truck and rail crew members would receive the highest doses. The mostly rail scenario would require transport crews for legal-weight trucks (1,079 total shipments over 24 years) and for rail

Table 6-11. Population doses and radiological impacts from incident-free transportation for national mostly rail scenario.[a]

Category	Legal-weight truck shipments	Rail shipments[b,c]	Totals[d]
Involved workers			
Collective dose (person-rem)	360	3,300 - 4,300	3,700 - 4,600
Estimated LCFs[e]	0.14	1.3 - 1.7	1.5 - 1.9
Public			
Collective dose (person-rem)	130	1,100 - 1,500	1,200 - 1,600
Estimated LCFs	0.07	0.55 - 0.76	0.61 - 0.81

a. Impacts are totals for 24 years.
b. Barge transportation to a railhead on navigable waterways could be used for transportation from 17 commercial sites that do not have rail service but can load a rail cask. See Appendix J.
c. Includes impacts from intermodal transfer station operations.
d. Totals might differ from sums of values due to rounding.
e. LCF = latent cancer fatality.

Table 6-12. Estimated doses and radiological impacts to maximally exposed individuals for national mostly rail scenario.[a,b]

Receptor	Dose (rem)	Probability of latent fatal cancer
Involved workers		
Crew member (rail, heavy-haul truck, or legal-weight truck)	48[c]	0.02
Escort	48[c]	0.02
Inspector (rail)	34	0.014
Railyard crew member	4.2	0.0017
Public		
Resident along route (rail)	0.0016	0.0000008
Person in traffic jam (legal-weight truck)	0.016	0.000008
Person at service station (legal-weight truck)	0.075	0.000038
Resident near rail stop	0.29	0.00014

a. The assumed external dose rate is 10 millirem per hour at 2 meters (6.6 feet) from the vehicle for all shipments.
b. Totals for 24 years.
c. Based on 2-rem-per-year administrative dose limit. If a lower dose limit, for example 500 millirem per year, was imposed for transportation workers or state inspectors, maximally exposed individual doses would be lower. See DIRS 156764-DOE (1999, Article 211) for DOE guidance on occupational dose limits.

shipments. Individual crew members who operated legal-weight trucks and escorts for rail shipments could be exposed to as much as 48 rem over 24 years of operations (maximum exposure of 2 rem each year). State inspectors who would conduct frequent inspections of rail shipments could receive annual radiation doses as high as 1.4 rem (see Appendix J, Section J.1.3.2.2.2). Escorts traveling with rail shipments could be exposed to up to 48 rem over 24 years of operations (maximum exposure of 2 rem per year; see Appendix J, Section J.1.3.2.2.3).

Impacts from Vehicle Emissions. Less than 1 (a range from 0.55 to 0.77) fatality could result from exposure to vehicle emissions over 24 years under the mostly rail scenario. This potential would arise principally from exposure of people in urban areas to very small increases in levels of pollutants caused by vehicles transporting spent nuclear fuel and high-level radioactive waste.

6.2.4 ACCIDENT SCENARIOS

6.2.4.1 Loading Accident Scenarios

The analysis used existing information from several different sources (DIRS 104794-CRWMS M&O 1994, all; DIRS 103177-CP&L 1989, all; DIRS 103449-PGE 1996, all; DIRS 101816-DOE 1997, all) to estimate potential radiological impacts from accidents involving the loading of spent nuclear fuel or high-level radioactive waste for shipment and handling of shipping casks. As summarized below, the results in these sources indicate that, because no cask would be likely to be breached and thus no radionuclides released, there would be no or very small potential radiological consequences for the public and for workers from accidents in all cases. Appendix J, Section J.1.3.1, presents a description of typical operations for loading spent nuclear fuel in a shipping cask at a commercial facility.

Lift-handling incidents involving spent nuclear fuel in a transfer facility would have an estimated probability of 0.0001 (1 in 10,000) per handling operation (DIRS 104794-CRWMS M&O 1994, pp. 3 to 8). The estimated collective dose to workers from the incidents would be no more than 0.1 person-rem, and it would be much less to the public.

The total number of high-level radioactive waste canisters potentially handled would be approximately the same as the number of spent nuclear fuel canisters, and handling operations would be similar. DOE expects the consequences of handling incidents that involved high-level radioactive waste would be less than those involving spent nuclear fuel (DIRS 103237-CRWMS M&O 1998, p. 3). Thus, impacts from high-level waste handling would be less than the estimated 0.1 person-rem from a spent nuclear fuel handling accident.

Reports on independent spent fuel storage installations and previous DOE analyses provide further evidence of the low probable impacts associated with a loading accident. Safety analysis reports prepared for independent spent fuel storage installations at the Trojan Nuclear Station and the Brunswick Steam Electric Plant concluded that there would be no or low radiological consequences from accidents that could occur at such facilities (DIRS 103449-PGE 1996, Section 8.2; DIRS 103177-CP&L 1989, Section 8.2). This analysis examined the potential magnitude of impacts from spent nuclear fuel storage facility operations. Similarly, previous DOE analyses (DIRS 101816-DOE 1997, all; DIRS 104794-CRWMS M&O 1994, all) indicate that radiological consequences from accidents involving spent nuclear fuel and high-level radioactive waste management activities would be very small (Table 6-12). The low consequences listed in Table 6-13 are consistent with the results from an earlier DOE analysis (DIRS 104731-DOE 1986, Volume 2, p. xvii).

Table 6-13. Radiological consequences of accidents associated with handling and loading operations.

Affected group	Impact (per year)[a]	24-year impact	Source
Involved workers			
Maximally exposed involved worker			
Dose (rem)	0.0005	0.01	--[b]
Probability of LCF[c]	0.0000002	0.000005	--
Worker population			
Collective dose (person-rem)	0.1	2.4	DIRS 104794-CRWMS M&O (1994, p. 3-8)
Number of LCFs	0.00004	0.001	--
Noninvolved workers			
Maximally exposed noninvolved worker			
Dose (rem)	0.0002	0.005	--
Probability of LCF	0.00000005	0.000001	--
Public			
Maximally exposed individual			
Dose (rem)	0.0013	0.03	--
Probability of LCF	0.0000007	0.00002	--
Population			
Collective dose (person-rem)	0.000074	0.002	DIRS 104794-CRWMS M&O (1994, p. 3-8)
Number of LCFs	0.00000004	0.000001	--

a. Average annual impact for 24 years.
b. -- = determined by analysis.
c. LCF = latent cancer fatality.

6.2.4.2 Transportation Accident Scenarios

Accidents could occur during the transportation of spent nuclear fuel and high-level radioactive waste. This section describes the risks and impacts to the public and workers for a range of accident scenarios including those that are highly unlikely but that could have high consequences (called *maximum reasonably foreseeable accident scenarios*) and those that are more likely but that would have less severe consequences. The impacts would include those to the population and to hypothetical maximally exposed individuals. The following paragraphs describe the analysis approach. Appendix J, Section J.1.4, contains more details.

The analysis did not address accident impacts to workers apart from impacts to the public. For example, fatalities from train and truck accident scenarios would include fatalities for vehicle operators. The collective radiological risk from accidents to highway vehicle and train crews would be much less than for the public because of the large difference in the numbers of individuals that could be affected. In addition, based on national accident statistics, motor carrier and train operators are much less likely to be fatalities in nonradiological accidents than operators of other vehicles (DIRS 103410-DOT 1998, p. 30).

MAXIMUM REASONABLY FORESEEABLE ACCIDENT SCENARIOS

Maximum reasonably foreseeable impacts from accident scenarios for the transportation of spent nuclear fuel and high-level radioactive waste would be characterized by extremes of mechanical (impact) forces, heat (fire), and other conditions that would lead to the highest reasonably foreseeable consequences. For postulated accident scenarios such as these, the forces and heat would exceed the regulatory design limits of transportation cask structures and materials. (The performance of transportation casks was demonstrated through a combination of tests and analyses.) In addition, these forces and heat would be applied to the structures and surfaces of a cask in a way that would cause the greatest damage and bring about releases of radioactive materials to the environment. The most severe accident scenarios analyzed in this chapter would release radioactive material. These accident scenarios correspond to those in the highest accident severity category, which represent events that would be very unlikely but, if they occurred, would result in human health effect consequences.

In general, this EIS considers accidents with conditions that have a chance of occurring more often than 1 in 10 million times in a year to be reasonably foreseeable. Accidents and conditions less likely than this are not considered to be reasonably foreseeable.

The specific number, location, and severity of an accident can be predicted only in general terms of the likelihood of occurrence (the probability). Similarly, the weather conditions at the time an accident occurs cannot be precisely predicted. Therefore, the EIS analysis evaluated a variety of accident scenarios and conditions to understand the influence of various conditions on environmental impacts. The analysis of impacts to populations along routes assumed that an accident could occur at any location along a route.

The EIS analysis considered accident scenarios based on the 19 truck and 21 rail accident cases presented by DIRS 152476-Sprung et al. (2000, all). Appendix J, Section J.1.4.2.1, describes those cases and their derivations. In addition, the analysis estimated impacts of postulated releases from accident scenarios in three population zones—urban, suburban, and rural—under a set of meteorological (weather) conditions that represent the national average meteorology. The analysis used state-specific accident data, the lengths of routes in the population zones in states through which the shipments would pass, and the number of shipments that would use the routes to determine accident scenario probabilities.

The EIS analysis used the properties of a representative commercial spent nuclear fuel along with the properties for the 15 categories of DOE spent nuclear fuel and high-level radioactive waste described in Appendix A. Since the publication of the Draft EIS, DOE has reevaluated the properties of commercial spent nuclear fuel that it used in analyses of transportation accidents and determined that the representative spent nuclear fuel described in Appendix A is more appropriate for analysis of such accidents. Representative commercial spent nuclear fuel would be (1) fuel discharged after 14 years from a boiling-water reactor with a burnup of 40,000 megawatt-days per MTHM and (2) fuel discharged from a pressurized-water reactor after 15 years with a burnup of 50,000 megawatt-days per MTHM. Because representative spent nuclear fuel would be younger and have higher burnup than typical spent nuclear fuel, its relative health and safety hazard would be greater. In fact, the hazard is about 2 times greater. As a consequence, estimates of impacts of transportation accidents involving casks containing representative spent nuclear fuel would be about 2 times greater than if the casks contained typical spent nuclear fuel.

TRANSPORTATION EMERGENCIES

Under Section 180(c) of the Nuclear Waste Policy Act, as amended, the Department would provide technical assistance and funding for training of local and American Indian public safety officials of eligible states and tribes in relation to transportation under the Proposed Action. The training would cover safe routine transportation and emergency response procedures. DOE would also require its transportation contractors to comply with *Carrier and Shipper Responsibilities and Emergency Response Procedures for Highway Transportation Accidents Involving Truckload Quantities of Radioactive Materials* (DIRS 156289-ANSI 1987, Section 5.2). This standard requires the preparation of an emergency response plan and describes appropriate provisions of information and assistance to emergency responders. The standard also requires the carrier to provide appropriate resources for dealing with the consequences of the accident including isolating and cleaning up spills, and to maintain working contact with the responsible governmental authority until the latter has declared the incident to be satisfactorily resolved and closed. DOE would, as requested, assist state, tribal, and local governments in several ways to reduce the consequences of accidents related to the transportation of spent nuclear fuel and high-level radioactive waste. In addition, DOE maintains an emergency response program through eight Regional Coordinating Offices across the United States. These offices are capable of responding to transportation radiological emergencies and are on call 24 hours a day. They respond to requests for radiological assistance from state or tribal authorities. Other DOE, Federal Emergency Management Agency, and U.S. Department of Transportation programs have provided training for transportation emergencies for many areas (for example, Colorado and South Carolina to support preparation for transportation for the Foreign Research Reactor and Waste Isolation Pilot Plant programs). Appendix M contains additional detail.

In addition to the risk due to accidents involving a release of radioactive material, the analysis examined the impacts of loss-of-shielding accidents. The loss-of-shielding scenarios range from an accident with no loss of shielding to a low-probability severe accident involving both a loss of shielding (and any increased direct exposure) and a release of some of the contents of the cask.

The EIS analysis also estimated impacts from an unlikely but severe accident scenario called a *maximum reasonably foreseeable accident* to provide perspective about the consequences for a population that might live nearby. For maximum reasonably foreseeable accident scenarios, the consequences were estimated for each of the accident scenarios and for both truck and rail casks from the spectrum of accidents presented in DIRS 152476-Sprung et al. (2000, all). For each accident scenario, possible combinations of weather conditions, population zones, and transportation modes were considered. The scenarios were then ranked according to those that would have a likelihood greater than 1 in 10 million per year and would have the greatest consequences (see Appendix J).

REEXAMINATION OF SPENT FUEL SHIPMENT RISK ESTIMATES

Factors other than the environment can cause uncertainties in the prediction of accident impacts. Uncertainty can result from both limited data and the limitations of computer models used to predict accident impacts. The first comprehensive study that developed estimates of the impacts of severe accidents was the *Shipping Container Response to Severe Highway and Railway Accident Conditions* (DIRS 101828-Fischer et al. 1987, all; also called the *Modal Study*) for fractions of shipping cask contents (spent nuclear fuel or high-level radioactive waste) that such accident scenarios could release to the environment. The estimates of severe accident impacts developed in the Modal Study were reexamined by Sandia National Laboratories in *Re-Examination of Spent Fuel Shipment Risk Estimates* (DIRS 152476-Sprung et al. 2000, all) published in April 2000. The Nuclear Regulatory Commission staff, in a memorandum to the Commissioners, concluded "the best estimate spent-fuel shipment risks from the reexamination appear to be less than the 'Modal Study'-based estimates by as much as 2 orders of magnitude" (DIRS 155562-NRC 2000, all). Although the Commission staff offered this positive finding, it also observed that several questions on the Sandia methodology require resolution before the best-estimate results can be completed. Even though it expressed caution regarding its findings, on the basis of the results presented the Commission staff concluded "the transportation risk studies provide a technical basis for determining that current regulations are sufficient to prevent releases of radioactive material during transport" (DIRS 155562-NRC 2000, all).

6.2.4.2.1 *Impacts from Accidents – National Mostly Legal-Weight Truck Scenario*

This section summarizes the potential impacts and risks associated with accidents under the legal-weight truck scenario. The impacts and risks include those associated with the legal-weight truck and rail shipments to Nevada plus the transfer of the spent nuclear fuel and high-level waste to heavy-haul trucks and its transportation in Nevada. The section summarizes radiological impacts for six accident scenario categories, under two types of weather conditions, and in three population densities (urban, suburban, and rural), in terms of a collective dose risk and consequence (latent cancer fatalities). It describes the potential impacts from the maximum reasonably foreseeable accident scenario separately. It also describes nonradiological impacts in terms of accident fatalities.

Radiological Impacts to Populations from Accidents. Based on state-specific accident rates, the total estimated number of traffic accidents under the Proposed Action for the mostly legal-weight truck scenario would be 66, or 2.8 per year. The collective radiological accident dose risk, as described in Appendix J, Section J.1.4.2.1, would be less than 1 (0.5) person-rem for the population within 80 kilometers (50 miles) along routes for the national mostly legal-weight truck scenario. This calculated risk would be the total for 24 years of shipment operations. The radiological dose risk of accidents is the sum of the products of the probabilities (dimensionless) and consequences (in person-rem) of all potential transportation accidents. A radiological dose risk of 0.5 person-rem would be likely to cause much less than 1 (0.0002) latent cancer fatality, or approximately 2 chances in 10,000 of 1 latent cancer fatality among the more than 10 million persons within 80 kilometers of the routes that the shipments would use. The 0.5 person-rem risk includes the dose risk associated with loss-of-shielding events. The accident risk for legal-weight truck shipments dominates the total risk, contributing more than 99.9 percent of the population dose and risk in comparison to the risk associated with the 300 proposed shipments of naval spent nuclear fuel.

Consequences of Maximum Reasonably Foreseeable Accident Scenario. The analysis evaluated the impacts of a maximum reasonably foreseeable accident scenario in urbanized and rural population zones for both legal-weight truck and rail shipments under the mostly legal-weight truck scenario. The maximum reasonably foreseeable transportation accident scenario that would have the greatest consequences for the mostly legal-weight truck scenario (a probability of approximately 3 in 10 million per year) would be a long-duration severe fire accident in which the transportation cask was fully engulfed by the fire. This accident is further described by DIRS 152476-Sprung et al. (2000, p. 7-25) as case 18 in accidents evaluated for legal-weight truck casks (see Appendix J, Section J.1.4.2.1). The analysis assumed that the accident would occur under stable (slowly dispersing atmospheric conditions that would not be exceeded 95 percent of the time) meteorological conditions in an urban area. Severe accidents in other population zones under stable or neutral weather conditions (atmospheric conditions that would not be exceeded 50 percent of the time) would have smaller consequences. The accident scenario assumes a breach of the shipping cask and the release of a portion of its contents to the air. This accident in combination with stable atmospheric conditions would be very unlikely (2.3 in 10 million per year). Table 6-14 summarizes the impacts of the accident scenario. This accident scenario could cause 0.55 latent cancer fatality; in comparison, a population of 5 million within 80 kilometers (50 miles) of the center of a large U.S. metropolitan area such as that assumed in the analysis would be likely to experience more than 1.1 million lifetime cancer fatalities from other causes not related to the Proposed Action (DIRS 153066-Murphy 2000, p. 5). For this accident scenario, the analysis projected that most of the dose to a population would come from inhalation, cloudshine, and groundshine sources. The maximally exposed individual, assumed to be about 150 meters (490 feet) from the accident where particles heated by the accident would fall after cooling, would receive a dose of about 0.8 rem (Table 6-14). A first responder to this accident would receive a small dose (2.6 millirem).

Table 6-14. Estimated radiological impacts of maximum reasonably foreseeable accident scenario for national mostly legal-weight truck scenario.

Impact	Urbanized area (stable atmospheric conditions)
Accident scenario probability (annual)	0.00000023 per year (about 2.3 in 10 million)
Impacts to populations	
Population dose (person-rem)	1,100
Latent cancer fatalities	0.55
Impacts to maximally exposed individuals	
Maximally exposed individual dose (rem)	3
Probability of a latent cancer fatality	0.0015
Impacts to first responder	
Maximally exposed responder dose (rem)	0.26
Probability of latent cancer fatality	0.0000013

In addition to a maximum reasonably foreseeable accident, DOE evaluated other severe accidents. Appendix J, Section J.1.4.2.1, describes these accidents and their potential impacts. The accident conditions for one truck accident (Case 11) could be similar to those from a crash of a commercial jet airliner into a legal-weight truck cask (DIRS 157210-BSC 2001, all). The consequences of this accident (1,100 person-rem or 0.55 latent cancer fatality) would be about the same as those for the maximum reasonably foreseeable truck accident described above.

Section J.1.4.2.5 in Appendix J summarizes studies of potential economic and environmental impacts of hypothetical severe transportation accidents that would release radioactive materials from transportation casks.

Impacts from Traffic Accidents. Approximately 5 (4.9) traffic fatalities could occur in the course of transporting spent nuclear fuel and high-level radioactive waste under the mostly legal-weight truck national transportation scenario during the 24 years of operations for the Proposed Action. Essentially all of these fatalities would be from truck operations; none would occur from the 300 railcar shipments of naval spent nuclear fuel. The fatalities would be principally from traffic accidents; half would involve trucks transporting loaded casks to the repository and half would involve returning shipments of empty casks. The fatalities would occur over 24 years and approximately 380 million kilometers (240 million miles) of highway travel. Based on information extrapolated from the U.S. Department of Transportation

Bureau of Transportation Statistics (DIRS 150989-BTS 1998, p. 20), during the same 24-year period about 1 million deaths would be likely to occur in traffic accidents on U.S. highways.

6.2.4.2.2 *Impacts from Accidents – National Mostly Rail Transportation Scenario*

This section discusses the results of the analysis of radiological impacts to populations and maximally exposed individuals and of traffic fatalities that would arise from accidents during the transportation of spent nuclear fuel and high-level radioactive waste for the national mostly rail transportation scenario.

DOE used the models and calculations described in Appendix J, Section J.1.4.2.1, to estimate the impacts from rail accidents, and included impacts postulated to occur during the transportation of commercial spent nuclear fuel by legal-weight trucks from six commercial sites that do not have the capability to handle or load large rail casks. The analysis also included the impacts from accidents for heavy-haul truck or barge shipments to nearby railheads from 24 commercial sites that have the capability to load a rail cask but are not served by a railroad. DOE used the models and calculations described in Appendix J to estimate the impacts. Appendix J, Section J.2.4, presents additional information on heavy-haul truck and barge transportation from the 24 commercial sites.

Accident Radiological Impacts for Populations. Based on state-specific accident rates, the total estimated number of rail and truck traffic accidents under the Proposed Action for the mostly rail scenario would be about 10, or about 0.4 per year. The collective radiological dose risk of accidents would be approximately 1 (0.89) person-rem for the population within 80 kilometers (50 miles) along routes for the national mostly rail transportation scenario. This calculated dose risk would be the total for 24 years of shipment operations. The radiological dose risk of accidents is the sum of the products of the probabilities (dimensionless) and consequences (in person-rem) of all potential transportation accidents. A radiological dose risk of 1 person-rem would be likely to cause much less than 1 (0.00045) latent cancer fatality.

Radiological risks from accidents for the mostly rail scenario would include impacts associated with about 9,646 railcar shipments (one cask to a railcar) and 1,079 legal-weight truck shipments. National rail transportation of spent nuclear fuel and high-level radioactive waste would account for most of the population dose and risk to the public.

Impacts of Maximum Reasonably Foreseeable Accident Scenario. The analysis evaluated the impacts of a maximum reasonably foreseeable accident scenario in urbanized areas or rural population zones and under stable and neutral atmospheric conditions. The maximum reasonably foreseeable accident scenario under the mostly rail scenario would involve a release of a fraction of the contents of a rail cask in an urban area under stable meteorological conditions (slowly dispersing atmospheric conditions that would not be exceeded 95 percent of the time), where *atmospheric dispersion* of contaminants would occur more slowly only 5 percent of the time. This accident scenario would have a likelihood of about 2.8 in 10 million per year, and would result in about 5 latent cancer fatalities in the population (Table 6-15). The maximally exposed individual, assumed to be about 330 meters (1,080 feet) from the accident, would receive a dose of about 29 rem. An accident that involved high impact forces or a long-duration fire could reduce the effectiveness of the radiation shielding in a shipping cask. A first responder to this accident could receive a dose of as much as 0.83 rem.

Actual transportation accidents involve collisions of many kinds, such as with other vehicles and roadside objects, involvement in fires and explosions, inundation, and burial. These accidents are caused by a variety of initiating events including human error, mechanical failure, and natural causes such as earthquakes. Accidents occur in many different kinds of places including mountain passes and urban areas, rural freeways in open landscapes, and rail switching yards. Thus, there are as many different kinds of unique initiating events and accident conditions as there are accidents. DOE could not

Table 6-15. Estimated impacts from maximum reasonably foreseeable accident scenario for national mostly rail transportation scenario.

Impact	Urbanized area (stable atmospheric conditions)
Accident probability	0.00000028 per year (about 2.8 in 10 million)
Impacts to populations	
Population dose (person-rem)	9,900
Latent cancer fatalities	5
Impacts to maximally exposed individuals	
Maximally exposed individual dose (rem)	29
Probability of a latent cancer fatality	0.01
Impacts to first responder	
Maximally exposed responder dose (rem)	0.83
Probability of latent cancer fatality	0.0004

practicably attempt to analyze every possible accident that could occur. Instead, DOE analyzed a broad range of accidents, each of which represents a grouping of initiating events and conditions having similar characteristics. For example, the EIS analyzes the impacts of a collection of collision accidents in which a cask would be exposed to impact velocities in the range of 60 to 90 miles per hour (see Appendix J, Section J.1.4.2.1).

In addition, the EIS analyzes a maximum reasonably foreseeable accident in which a collision would not occur but the temperature of a rail cask containing spent nuclear fuel would rise to between 750ºC and 1,000ºC (between 1,400ºF and 1,800ºF) (Section 6.2.4.2). The conditions of the maximum reasonably foreseeable accident analyzed in the EIS envelop conditions reported in newspapers for the Baltimore Tunnel fire (a train derailment and fire that occurred in July 2001 in a tunnel in Baltimore, Maryland). Temperatures in that fire were reported to be as high as 820ºC (1,500ºF) and the fire was reported to have burned for up to 5 days (DIRS 156753-Ettlin 2001, all; DIRS 156754-Rascovar 2001, all).

DOE evaluated other severe accidents. Appendix J, Section J.1.4.2.1, describes these accidents and their potential impacts. The accident conditions for one rail accident (Case 4) could be similar to those from a crash of a commercial jet airliner into a rail cask (DIRS 157210-BSC 2001, all). The consequences of this accident (1,300 person-rem or 0.65 latent cancer fatality) would be less than those for the maximum reasonably foreseeable rail accident described above.

Impacts From Traffic Accidents. The analysis estimated that across the United States approximately 3 (3.1) traffic and train accident fatalities could occur during transportation of spent nuclear fuel and high-level radioactive waste under the national mostly rail transportation scenario. Half of the fatalities would occur during the return of empty casks to commercial and DOE sites. Essentially all of the fatalities would involve train operations; about half would involve highway vehicles hit by trains. There would be about a 12-percent chance of 1 fatality from the 1,079 legal-weight truck shipments of commercial spent nuclear fuel. This fatality could happen during the 24 years of transportation operations involving approximately 77 million kilometers (48 million miles) of railcar travel and 10 million kilometers (6 million miles) of highway travel. On the basis of data presented by the Bureau of Transportation Statistics (DIRS 150989-BTS 1998, p. 20), during the same 24-year period about 1 million people will die in traffic accidents on U.S. highways.

6.2.4.2.3 *Impacts of Acts of Sabotage*

The Nuclear Regulatory Commission has developed a set of rules specifically aimed at protecting the public from harm that could result from sabotage of spent nuclear fuel casks. Known as physical protection and safeguards regulations (10 CFR 73.37), these security rules are distinguished from other regulations that deal with issues of safety affecting the environment and public health. The objectives of the physical protection and safeguard regulations are to:

- Minimize the possibility of sabotage
- Facilitate recovery of spent nuclear fuel shipments that could come under control of unauthorized persons

To achieve these objectives, the Nuclear Regulatory Commission physical protection and safeguard rules require:

- Advance notification of each shipment to the Nuclear Regulatory Commission, the states, and Native American governments [proposed rulemaking 10 CFR Parts 71 and 73 (64 *FR* 71331, December 21, 1999)]
- The licensee to have current procedures to cope with safeguards emergencies
- Instructions for escorts on how to determine if a threat exists and how to deal with it
- Maintenance of a communications center to monitor continually the progress of each shipment
- A written log describing the shipment and significant events during the shipment
- Advance arrangements with law enforcement agencies along the route
- Advance route approval by the Nuclear Regulatory Commission
- Avoidance of intermediate stops to the extent practicable
- At least one escort to maintain visual surveillance of the shipment during stops
- Shipment escorts to report status periodically
- Armed escorts in heavily populated areas
- Onboard communications equipment
- Protection of specific shipment information

The cask safety features that provide containment, shielding and thermal protection also provide protection against sabotage. The casks would be massive. The spent nuclear fuel in a cask would typically be only about 10 percent of the gross weight; the remaining 90 percent would be shielding and structure.

It is not possible to predict whether sabotage events would occur and, if they did, the nature of such events. Nevertheless, DOE examined various accidents, including an aircraft crash into a transportation cask. The consequences of both the maximum reasonably foreseeable accident and the aircraft crash are presented above for the mostly truck and mostly rail transportation scenarios and can provide an approximation of the types of consequences that could occur from a sabotage event. DOE also considered the consequences of a potential successful sabotage attempt on a cask. A study conducted by Sandia National Laboratories (DIRS 104918-Luna, Neuhauser, and Vigil 1999, all) estimated the amounts and characteristics of releases of radioactive materials from rail and truck casks subjected to the effects of two different devices.

Devices considered in the Sandia study (DIRS 104918-Luna, Neuhauser, and Vigil 1999, all) included possible devices that might be used in acts of sabotage against shipping casks. (Note: The shield walls of shipping casks for spent nuclear fuel and high-level radioactive waste are similar to the massive layered construction used in armored vehicles such as tanks.) These kinds of devices were demonstrated by the study to be capable of penetrating a cask's shield wall, leading to the dispersal of contaminants to the environment.

The truck cask design selected for analysis was the General Atomics GA-4 Legal-Weight Truck Cask. This cask, which uses uranium for shielding, is a state-of-the-art design recently certified by the Nuclear Regulatory Commission to ship four pressurized-water reactor nuclear fuel assemblies (DIRS 148184-NRC 1998, all). The rail cask design used was based on the conceptual design developed by DOE for the dual-purpose canister system. This design is representative of large rail casks that could be certified for shipping spent nuclear fuel and high-level radioactive waste.

DOE used the RISKIND code (DIRS 101483-Yuan et al. 1995, all) to evaluate the radiological health and safety impacts of the estimated releases of radioactive materials. The analysis used assumptions about the concentrations of radioisotopes in spent nuclear fuel, population densities, and atmospheric conditions (weather) used to evaluate the maximum reasonably foreseeable accidents.

Because it is not possible to forecast the location or the environmental conditions that might exist for acts of sabotage, the analysis determined consequences for urbanized areas (see Appendix J, Section J.1.4.2.1) under neutral (average) weather conditions.

For legal-weight truck shipments, the analysis estimated that a sabotage event occurring in an urbanized area could result in a population dose of 96,000 person-rem. This dose would cause an estimated 48 fatal cancers among the population of exposed individuals. A maximally exposed individual could receive a lifetime committed dose of 110 rem, which would increase the risk of a fatal cancer from about 23 percent from all other causes to about 29 percent.

These estimates exceed those presented in the Draft EIS for two reasons. The analysis for this section assumed that the cask would contain representative (or average hazard) spent nuclear fuel. The analysis in the Draft EIS assumed that the cask would contain typical (or average age) spent nuclear fuel. The amount of radioactivity in representative spent nuclear fuel is about twice that in typical spent nuclear fuel. In addition, the analysis in the Draft EIS used urban area populations reported in the 1990 Census, whereas the analysis for this section used populations projected to 2035. The population estimates used for 2035 are about 40 percent greater than those reported by the 1990 Census. The combined result of these changes is that the estimated consequences of an act of sabotage against a transportation cask in this section are about 3 times those estimated in the Draft EIS.

The consequences estimated for an act of sabotage involving a rail shipment would be less than those estimated for a legal-weight truck shipment. The smaller consequence for the rail shipment would be because less of the radionuclides would be released from a rail transportation cask than from a legal-weight truck transportation cask (DIRS 104918-Luna, Neuhauser, and Vigil 1999, all). For rail shipments, the analysis estimated that a sabotage event in an urbanized area could result in a population dose of 17,000 person-rem. This dose would be likely to cause an estimated 9 fatal cancers among the population of exposed individuals. A maximally exposed individual could receive a lifetime committed dose of 40 rem, which would increase the risk of a fatal cancer from about 23 percent from all other causes to about 25 percent.

Because of the attacks on September 11, 2001, the Department and other agencies are reexamining the protections built into our physical security and safeguards systems for transportation shipments. As dictated by results of this reexamination, DOE would modify its methods and systems as appropriate.

6.2.5 ENVIRONMENTAL JUSTICE

Shipments of spent nuclear fuel and high-level radioactive waste would use the Nation's existing railroads and highways. DOE expects that transportation-related impacts to land use; air quality; hydrology; biological resources and soils; cultural resources; socioeconomics; noise and vibration; aesthetics; utilities, energy, and materials; and waste management would be small. In addition, as described in the preceding sections, incident-free transportation and the risks from transportation accidents (the maximum reasonably foreseeable accident scenario would have about 3 chances in 10 million of occurring per year) would not present a large health or safety risk to the population as a whole, or to workers or individuals along national transportation routes. The low effect on the population as a whole also would be likely for any segment of the population, including minorities, low-income groups, and members of Native American tribes.

A previous DOE analysis of the potential for environmental justice concerns from the transportation of DOE spent nuclear fuel to the Idaho National Engineering and Environmental Laboratory (DIRS 101802-DOE 1995, Volume 1, pp. L-2 and L-36) also concluded that impacts to minority and low-income populations and to populations of American Indians in Idaho would not be disproportionately high and adverse. As part of that analysis, DOE consulted with the Shoshone Bannock Tribe to analyze impacts to tribe members because the shipments in question would cross the Fort Hall Reservation. The analysis (DIRS 101802-DOE 1995, Volume 3, Part A, p. 3-32) concluded that risks to the health and safety of the potentially affected tribal population in Idaho from incident-free transportation and from accidents would be very low.

The EIS analyzes potential public health effects of both routine (incident-free) transportation of radioactive materials and transportation accidents involving radioactive materials. First, regarding routine transportation, the EIS considers air emissions and doses from exposure to radioactive materials during transport. The EIS estimates the impact from air emissions to be 1 emissions-related fatality. The EIS also estimates that the 24-year national transportation campaign would cause fewer than about 3 latent cancer fatalities among the public under the mostly legal-weight truck scenario and fewer under the preferred mostly rail scenario. Although many people would be exposed nationwide over a long campaign, the radiation dose to any exposed individual would be very low. In this context, DOE does not consider such impacts to be high. Because DOE does not know of a plausible mechanism under these circumstances whereby low-income or minority populations could incur high and adverse impacts when the general public would not, the Department believes there could be no disproportionately high and adverse impacts on low-income or minority populations.

The EIS estimates the number of people in the general public who could be killed by accidents involving transportation of spent fuel and high-level radioactive waste. The two mechanisms for such impacts are bodily trauma from collisions or exposure to radioactivity that would be released if a sufficiently severe accident occurred. The analysis estimated that the 24-year national campaign would cause fewer than 5 fatalities among the general public from trauma sustained in collisions with vehicles carrying spent nuclear fuel or high-level radioactive waste. In this context, DOE does not consider such impacts to be high. Again, DOE does not know of a plausible mechanism under these circumstances whereby low-income or minority populations could incur high and adverse impacts when the general public would not.

Only a severe accident that resulted in a considerable release of radioactive material could cause high and adverse health effects to the affected population. Because the risk of these high and adverse consequences applies to the entire population along all transportation routes, it would not apply disproportionately to any minority or low-income population.

Based on the analysis of incident-free transportation and transportation accidents in this EIS and the results of a transportation analysis conducted by DOE in a previous programmatic EIS, and the fact that

DOE has identified no subsection of the population that would be disproportionately affected by transportation related to the Proposed Action, DOE has concluded that no disproportionately high and adverse impacts would be likely on minority or low-income populations from the national transportation of spent nuclear fuel and high-level radioactive waste to Yucca Mountain.

Section 6.3.4 discusses environmental justice in relation to transportation in Nevada. Chapter 4, Section 4.1.13.4, contains a discussion of a Native American perspective on the Proposed Action.

6.3 Nevada Transportation

The analysis of impacts from national transportation includes those from transportation activities in the State of Nevada. This section discusses Nevada transportation impacts separately to ensure that the impacts of alternative transportation modes in Nevada are apparent. Spent nuclear fuel and high-level radioactive waste shipped to the repository by legal-weight truck would continue in the same vehicles to the Yucca Mountain site. Material that traveled by rail would either continue to the repository on a newly constructed branch rail line or transfer to heavy-haul trucks at an intermodal transfer station that DOE would build in Nevada for shipment on existing highways that could require upgrades. Selection of a specific rail alignment within a corridor, or the specific location of an intermodal transfer station or the need to upgrade the associated heavy-haul truck routes, would require additional field surveys, environmental and engineering analysis, state, local, and Native American Tribal government consultation, and National Environmental Policy Act reviews.

The transportation analysis in the EIS treats the candidate legal-weight truck routes, rail corridors, and heavy-haul truck routes as current analysis tools and refers to them in the present tense. The EIS refers to impacts associated with these alternatives in the conditional voice *(would)* because they would not occur unless DOE proceeded with the Proposed Action. This convention is applied whenever the EIS discusses the transportation implementing alternatives.

This section describes potential impacts of three transportation scenarios and their respective implementing alternatives. The three transportation scenarios are (1) mostly legal-weight truck (corresponding to that portion of the national impacts that would occur in Nevada), (2) mostly rail, and (3) mostly heavy-haul truck.

The mostly legal-weight truck scenario does not include implementing alternatives. Under this scenario, highway shipments would be restricted to specific routes that satisfy the regulations of the U.S. Department of Transportation (49 CFR Part 397). Because the State of Nevada has not designated alternative preferred routes, only one combination of routes for legal-weight truck shipments would satisfy U.S. Department of Transportation routing regulations (I-15 to U.S. Highway 95 to Yucca Mountain). This scenario assumes that over 24 years approximately 300 shipments of naval spent nuclear fuel would arrive in Nevada by rail from the Idaho National Engineering and Environmental Laboratory and that heavy-haul trucks would transport them to the repository from a railhead.

The mostly rail scenario has five implementing alternatives, each of which includes a corridor with variations for a branch rail line in Nevada. Each implementing alternative includes the construction and operation of a rail line. These alternatives would include about 1,079 legal-weight truck shipments (about 45 per year) from 6 commercial sites that, while operational, would not have the capability to load rail casks.

The mostly heavy-haul truck scenario has implementing alternatives for five different routes on existing Nevada highways. The highways would have to be upgraded to enable heavy-haul trucks routinely to transport rail casks containing spent nuclear fuel and high-level radioactive waste from an intermodal transfer station to the repository. Each heavy-haul truck implementing alternative includes the